LiFS: An Attribute-Rich File System for Storage Class Memories

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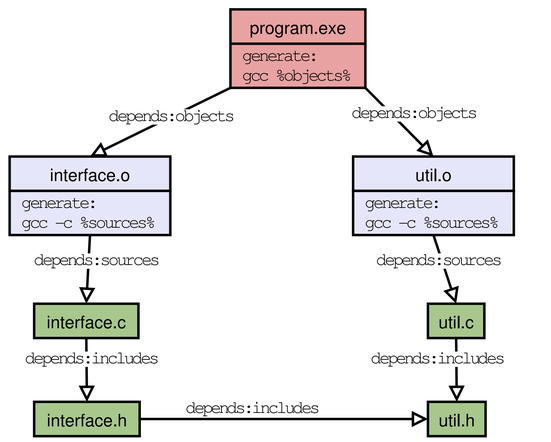
Motivation

- The amount and variety of data stored has grown much faster than existing file systems.
- Many applications keep their own metadata stores, e.g. iTunes, e-mail clients, etc. These systems:
  - are application-specific
  - add significant complexity
- It is often easier to search the web than the local file system
  - Web search engines such as Google can take advantage of a rich hyperlink structure.
  - Similar contextual data in the filesystem would enhance local file searches.

LiFS

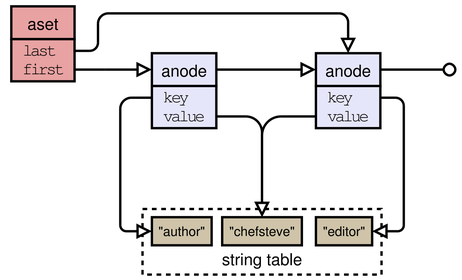
- Incorporating rich metadata into the filesystem itself simplifies sharing between applications.
- Applications need only create metadata, not store it.
- LiFS (The Linking FileSystem) introduces the relational link as a unit of file metadata.
  - Link files with $\langle key, value \rangle$ pairs expressing their relationship.
  - Traditional directories are 0-byte files with outgoing links.



A compiler dependency graph represented with relational links

Design

- Designed to use non-volatile memory for metadata storage
  - Fast storage-class memories provide speed necessary for searching rich metadata structures
  - Random access memories allow for simpler, efficient code
    - Linked lists store objects rather than trying to lay out structures on a disk block
    - A string table saves space and allows for easy string comparisons



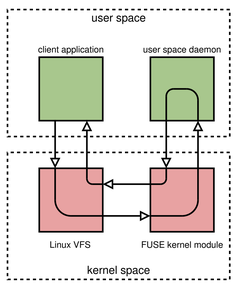
A set of attributes from a link or file

- Several new system calls have been introduced to manipulate relational links

System call	Function
rellink	Create a new relational link between files
rmlink	Remove a relational link between files
setlinkattr	Set attributes on an existing link between files
openlinkset	Returns an identifier for a set of links from a source file
readlinkset	Fills in standard directory entry structure with link name and attributes for the next link in a set

Implementation

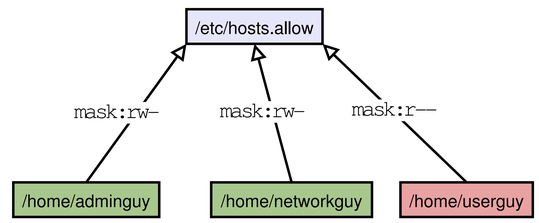
- LiFS was implemented through FUSE (Filesystem in Userspace)
  - Prototype LiFS without complexity of in-kernel development
  - Even with significant performance overhead of FUSE, LiFS' performance is competitive with existing kernelspace filesystems



Future Work

- In-kernel implementation of LiFS
  - Allows for better comparison with existing filesystems
  - Because FUSE is designed around existing POSIX interfaces, adding new functionality is difficult.
- Take advantage of relational links in file searches
  - What kinds of new queries can users take advantage of?
  - How should searching be presented to the user?
    - Existing approaches often use directory components as search terms, e.g. `/search/owner:john/type:mp3/`

- Can LiFS metadata be stored with other storage technologies?
  - LiFS on disk
    - Seek time of disk accesses makes searching link structures difficult
    - A number of graph indexing solutions exist which might make LiFS on disk possible
  - LiFS in flash
    - Different flash technologies have different access properties
    - Flash has a limited number of writes per block
    - To change data, an entire block must be erased and rewritten
  - LiFS implemented using extended attributes
    - System would be backwards-compatible
    - Standard xattr interface is inefficient



An ACL implemented using relational links

- Many different paths can exist to a single file
- Allowing path to modify file access is a powerful tool
  - Security
    - Providing users links to files might replace complex ACLs
  - Modifying file data
    - Individual links might serve to compress/encrypt file data
    - Files might be defined as an aggregation of linked files